Experimental Validation and Data-Driven Integration of Electrical Propulsion Drive System (EPDS) Components for Software-Defined Vehicles (SDV)

Summary

This PhD project focuses on the empirical validation and intelligent data integration of Electrical Propulsion Drive System (EPDS) components in Software-Defined Vehicles (SDVs). Building upon the foundational modeling and digital twin frameworks developed within the realization of the PRG2532 project, this research will deliver comprehensive testing protocols, advanced data pre-processing strategies, and condition monitoring solutions for EPDS subsystems.

Research field:	Electrical power engineering and mechatronics
Supervisor:	Prof. Dr. Anton Rassõlkin
Availability:	This position is available.
Offered by:	School of Engineering Department of Electrical Power Engineering and Mechatronics
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The main objective of this research is to bridge the gap between model-based development and real-world performance of EPDS components by developing robust methodologies for experimental validation and data acquisition. A particular focus will be placed on integrating sensor-driven data streams and historical datasets into the hybrid digital twin framework, thus enhancing the reliability, safety, and efficiency of SDVs throughout their lifecycle—from design and manufacturing to operation and maintenance.

The PhD candidate will be responsible for experimental setups, in-situ data collection, and model validation processes. The outcome will include technical reports and strategic recommendations for embedding EPDS digital twins within the broader SDV ecosystem.The main tasks of the thesis are:

1. Understanding the role of experimental validation and data integration in EPDS for SDVs

- Conduct a comprehensive literature review focusing on the principles of experimental validation, condition monitoring, and data-driven integration in the context of EPDS for SDV.
- Analyze the theoretical foundations and practical applications of cyber-physical systems (CPS) and digital twins (DT) in EPDS to understand their role in enhancing reliability, safety, and predictive maintenance.
- Identify research gaps, methodological limitations, and opportunities for innovation in validating and integrating EPDS subsystems into SDV architectures.

2. Investigation of state-of-the-art validation methods and data preprocessing techniques

- Identify and review state-of-the-art technologies and methodologies related to CPSs, DTs, and SDVs.
- Explore recent advancements and emerging trends in these areas, including modeling techniques, simulation tools, scaled demonstrators, and integration strategies.
- Review and analyze existing analytical, numerical, and data-driven models from previous PSG453 and ongoing PRG2532 projects.
- Identify limitations of the existing EDPS and propose strategies for improvement.

3. Experimental validation of EPDS components

- Conduct comprehensive experimental testing of EPDS subsystems under varied environmental and operational conditions to validate models developed in previous PSG453 and ongoing PRG2532 projects.
- Analyze component behavior through controlled lab and field tests, comparing performance metrics against simulated outputs.

- Identify discrepancies and feedback results into model refinement to improve accuracy and robustness.

4. Data acquisition, cleansing, and pre-processing for digital twin development

- Identify and gather relevant data sources, including sensor outputs from EPDS systems and historical operation records.
- Apply advanced data cleansing techniques to correct or remove incomplete, corrupted, or duplicate entries and ensure consistency across datasets.
- Pre-process the raw data into a standardized format suitable for integration into data-driven modeling and digital twin frameworks.

5. Integration of condition monitoring into digital twin frameworks

- Integrate real-time and historical component condition monitoring data into the digital twin structure of WP2.
- Utilize sensor-based insights to inform testing strategies, improve operational efficiency, and enhance fault detection and predictive maintenance capabilities.
- Assess the impact of condition monitoring on system-level diagnostics, safety, and overall lifecycle performance of EPDS in SDVs.

The applicants should fulfill the following requirements:

- Master's degree in electrical engineering or mechatronics
- Hands-on experience with motor-drive components such as power electronics, motors, batteries, and sensors.
- Experience with common scientific software (e.g. Matlab, Simulink, Octave, Python, etc.)
- Experience with common research support software (e.g. Office 365, Mendelay, LateX, etc.)
- Practical experience with publishing and presenting research works (e.g. conference papers)
- Very good command of English

Fluent Estonian language skills in written and oral communication are desirable but not mandatory

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